The 6th **International Symposium on Artificial Intelligence, Robotics and Automation in Space** (i-SAIRAS-'01), Montreal, Canada, June 18-21, 2001.

Sample Acquisition and In-Situ Analysis Using the Ultrasonic/Sonic Driller/Corer (USDC) and Robotic platforms

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Future NASA exploration missions to Mars, Europa, Titan, comets and asteroids are seeking to perform sampling, in-situ analysis and possibly return sample materials to Earth for further tests. One of the major limitations of sampling in low gravity environments is the conventional drills need for high axial force and, as a result, heavy robotic mechanisms are required constraining missions possibilities. To overcome this and other limitations of existing drilling techniques, an ultrasonic/sonic driller/corer (USDC) mechanism was developed. The USDC is based on an ultrasonic horn that is driven by a piezoelectric stack, where the horn drives and resonates a free-mass located between the horn and the drill stem. Tests have shown that USDC addresses some of the key challenges to the NASA objective of planetary in-situ sampling and analysis. The USDC is lightweight (450 g), requires low preload (< 5N) and can be driven at low power (5W). The device was operated from such robotic platforms as the Sojourner rover and the FIDO robotic arm and it has been shown to drill various rocks including granite, diorite, basalt and limestone. The device can be operated to probe the sampled media both via self-sensing capability and onboard sensors and analyzers. The drill can potentially operate at high and low temperatures and does not require sharpening of the bit. Although the drill is driven electrically at 20 kHz, a substantial sub-harmonic acoustic component is found that is crucial to drilling performance. Analytical models that explain this low frequency coupling in the horn, free-mass, drill stem and rock were developed and are currently being integrated and corroborated experimentally. The results of the USDC research and development efforts so far and the potential applications of the device will be described in this paper.